Umpqua Basin Stream Temperature Characterization – Reference Site 2016 Update

(Covering Project Duration 1998-2016)

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This is the annual update of the Umpqua Basin Reference Stream Temperature Project, a long term temperature study. This report presents stream temperature conditions for 2016 and compares that to the air and stream temperature data collected since 1998 as well as flow data since 2004. The original study, the Umpqua Basin Stream Temperature Characterization Project, was conducted from 1998 – 2001 sampling approximately every ten square miles, to establish the range of variability of stream temperature in the Umpqua Basin temporally and spatially (Smith, 2001a). Air and stream temperature monitoring of five reference sites, chosen based on varying climatic conditions and drainage areas, has continued annually to document the patterns of stream temperatures in the Umpqua Basin (Smith, 2003, 2004, and 2005; Dammann and Smith, 2006; Dammann, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, and 2015). The data from these five sites (Calapooya, Camp, North Myrtle, Pass, and Windy Creeks) can be used as models to normalize for annual variability in other stream locations lacking long-term data, especially those with a short record of data such as restoration project monitoring sites. This normalization is achieved either by making an adjustment or comparison from the data by using the ratio method (Smith, 2001b), or the use of synoptic temperature data (Smith, 2010).

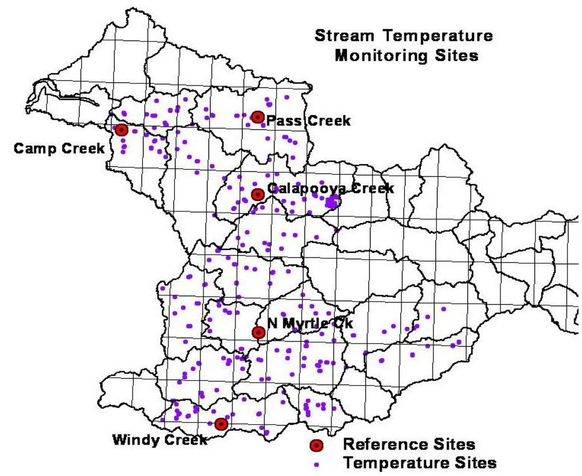

Photo 1: Rough-skinned newt (*Taricha granulosa*) at Camp Creek site.

This report will (1) analyze stream temperature patterns at the Umpqua basin reference temperature sites for this year as well as the period of record (2) look at effects of air temperature, flow, and day length on stream temperature at these sites, particularly flow using flow data collected at the sites (since 2004) by Oregon Water Resources Department (OWRD) for PUR and (3) present several methods of using the reference temperature data in conjunction with project data throughout the basin to reduce annual variability and to expand on project data lacking multiyear data.

2016 Regional and Reference Site Summer Flows and Air and Stream Temperature:

April, 2016 brought warm temperatures and rapid snowmelt to the mountains of Oregon, therefore the snowpack was diminished and stream flows were below normal by the beginning of May (U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), May 1, 2016). While the reference temperature sites do not have headwaters in the snow zone, they do in the transient snow zone and the flows were also lower in these sites as well in May and early June.

Stream temperature is affected by several factors. Radiant energy is one of these, with solar radiation being a very important factor in heating streams (Brown, 1969 and Beschta, *et al.*, 1987). Solar radiation reaching streams is reduced by canopy cover, but can change daily from changes in surface area due to changes in flow, changes in day length, changes in cloud cover, and changes in solar output (which is often expressed by air temperature changes). Stream flow is another important factor that will be discussed in detail later in this report.

The reference temperature sites are surrounded by the cities of Roseburg, Eugene, and Medford in Western and Southwestern Oregon; therefore, the temperature patterns and extremes at these sites follow those of these three cities (Tables 1 and 2). Overall June was warmer and dryer than usual in these cities, July was fairly mild, and August also had higher than normal temperatures (Iowa State University of Science and Technology, 2016 and NWS, 2016a and 2016b). There were heat waves in the region in late May/early June, late June, late July/early August, and much of the rest of August (Table 1). The highest temperatures were between August 11 and 20 (Table 1).

Table 1. Heat waves with consecutive high maximum daily air temperatures above 85°F in Roseburg, Oregon from May to September, 2016. All National Weather Service (NWS) data are preliminary and have not undergone final quality control. (Iowa State University of Science and Technology, 2016 and NWS, 2016a and 2016b)

Date Range	**Location**	**Daily Maximum Air Temperatures**
May 31 - June 7	Roseburg	85-97°F
June 26 – July 3	Roseburg	85-91°F
July 24 – August 5	Roseburg	86-99°F, with 81°F on August 2
August 11-20	Roseburg	92-108°F
August 21-29 (continued but cooler)	Roseburg	86-99°F

There were several record weather events that occurred in Roseburg, Eugene, and Medford throughout Summer, 2016 (Table 2). In addition to the record high maximum air temperatures throughout the summer, there were record high rainfalls in early July (Table 2). In Roseburg, the highest temperature of the summer was 107°F on August 19. For comparison, the highest temperature in 2015 was 108°F (NWS, 2015a) and the record high temperature for Roseburg is 109°F which occurred on July 20, 1946 (NWS, 2016a). Since solar radiation is an important factor affecting stream temperature (Brown, 1969 and Beschta, *et al.*, 1987), stream temperatures in the Umpqua Basin increased during these heat waves.

While Summer, 2016 was cooler, Summer, 2015 was the hottest summer on record for all three cities (Roseburg, Medford, and Eugene, Oregon) for which there is about 100-120 years of data (NWS, 2015a and 2015b). The next two hottest summers for Roseburg and Medford were 2014 followed by 2013. (The News-Review, September 2, 2015; The Register-Guard, September 2, 2015; and Mail Tribune, September 1, 2015).

Table 2. Record weather events for Roseburg, Medford, and Eugene, Oregon from May to September, 2016. All National Weather Service (NWS) data are preliminary and have not undergone final quality control. (Iowa State University of Science and Technology, 2016 and NWS, 2016a and 2016b)

Date	Location	Record Broken
May 2, 2016	Roseburg	Tie for highest maximum temperature for this date (86°F)
June 4, 2016	Roseburg	Highest maximum temperature for this date (97°F)
June 4, 2016	Medford	Tie for highest maximum temperature for this date (100°F)
June 4, 2016	Eugene	Highest maximum temperature for this date (95°F)
June 5, 2016	Eugene	Highest maximum temperature for this date (94°F)
July 7, 2016	Roseburg	Maximum rainfall for this date (0.20 inches)
July 8, 2016	Roseburg	Maximum rainfall for this date (0.52 inches)
August 6, 2016	Eugene	Tie for lowest minimum temperature for this date (42°F)
August 18, 2016	Medford	Highest maximum temperature for this date (108°F)
August 18, 2016	Eugene	Highest maximum temperature for this date (104°F)
August 19, 2016	Roseburg	Highest maximum temperature for this date (107°F)
August 19, 2016	Medford	Highest maximum temperature for this date (109°F)
August 20, 2016	Roseburg	Highest maximum temperature for this date (101°F)
August 20, 2016	Medford	Highest maximum temperature for this date (105°F)
August 26, 2016	Roseburg	Highest maximum temperature for this date (99°F)
September 26, 2016	Roseburg	Highest maximum temperature for this date (95°F)

Since 1998, summer air and stream temperature data were collected with continuous temperature recorders set for 30 minute intervals at the five reference sites. Since 2009, the period of record has been from at least June 21 to September 21; prior to 2009, it was collected from at least July 1 to mid-September. In 2016, air and stream temperature data was collected beginning June 5 (at North Myrtle Creek), June 6 (at Calapooya Creek), June 11 (at Windy Creek), and June 12 (at Camp and Windy Creeks) (Figures 1 and 2).

High air temperatures over several days appear to have a stronger effect on increased stream temperature compared with shorter periods of high temperatures since the streams don't have much opportunity for nighttime cooling. The heat waves at the reference sites corresponded with those in the surrounding cities. There were five of these heat waves during Summer, 2016, the strongest of which were May 31 to June 7, July 24 to August 5, and August 11 to August 20 (Table 1 and Figure 1). Stream temperatures rose at all five sites during these heat waves and we also very high during the June 26 to July 3 heat wave particularly at Calapooya Creek (Figures 1 and 2).

The 7-day average maximum (7DAM) stream temperature is a statistic used to describe the average of the maximum stream temperatures over a seven day period (described as occurring on the fourth date of that series, or center date). Two of the reference sites had their 7DAM stream temperature during the late July to early August heat wave (Camp and Windy Creeks) and three had their 7DAM stream temperature during the mid-August heat wave (Calapooya, North Myrtle, and Pass Creeks).

Interannual Variability of 7-Day Average Maximum (7DAM) Stream Temperatures and Importance of Normalization of Short-term Data Sets:

In 2016, the 7DAM stream temperatures for the reference sites exhibited similar patterns to previous years in the 17-18 year period of record. Calapooya Creek has had the highest 7DAM stream temperatures for the entire period of record and Windy Creek has had the lowest (Figure 3). Pass Creek and North Myrtle Creek continue to have similar 7DAM temperatures, varying from year to year on

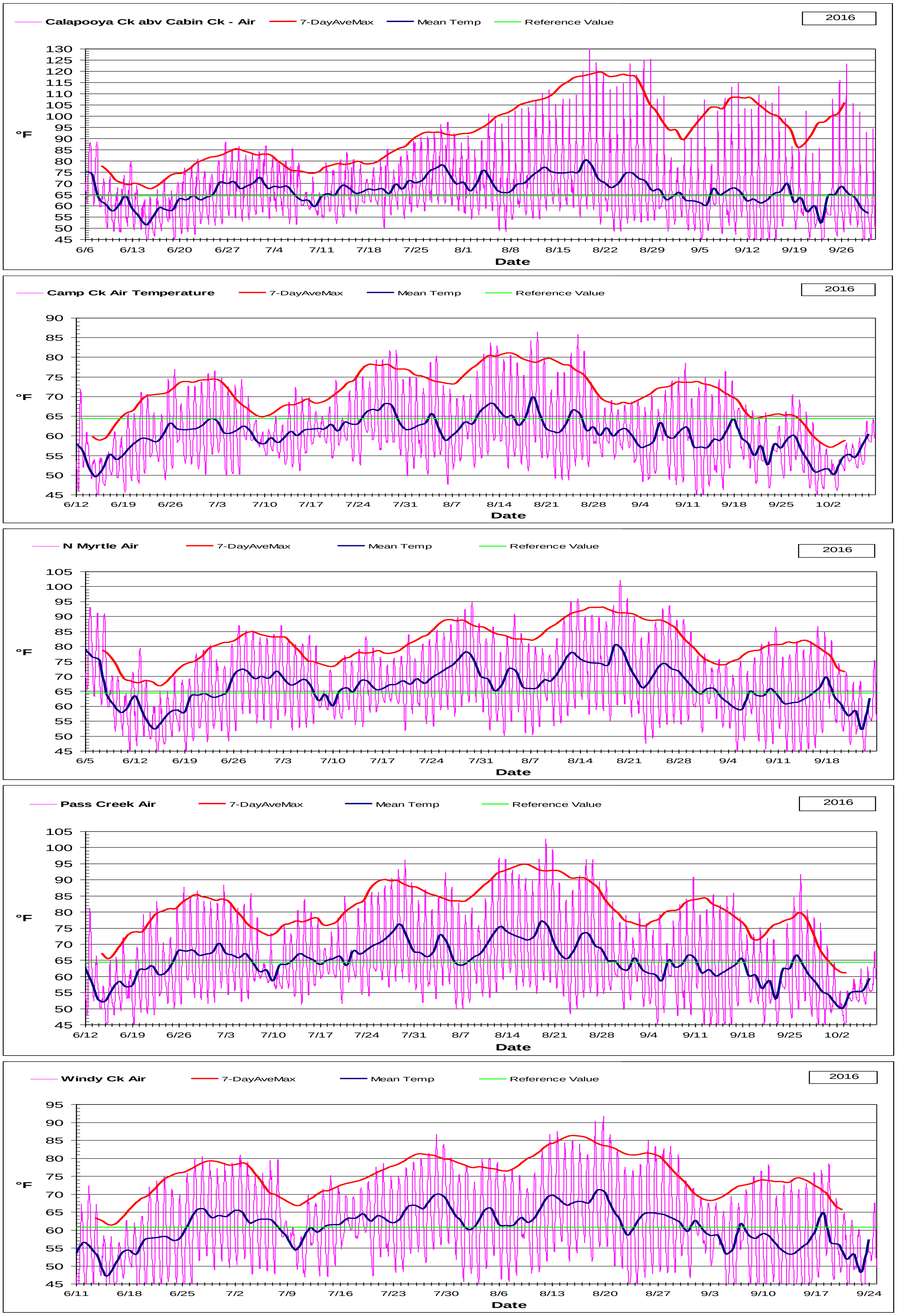

Figure 1. 2016 Umpqua Basin reference site air temperature data measured at 30-minute intervals. The reference value is set at the Oregon Department of Environmental Quality (ODEQ) temperature standard for stream temperature (64.4°F for all streams except Windy Creek which is 60.8°F (ODEQ 2003 & 2011)). Note the high air temperatures for Calapooya Creek beginning mid-August; the equipment was found at the end of the season uncovered and exposed to the daytime sun, so it probably became uncovered in mid-August.

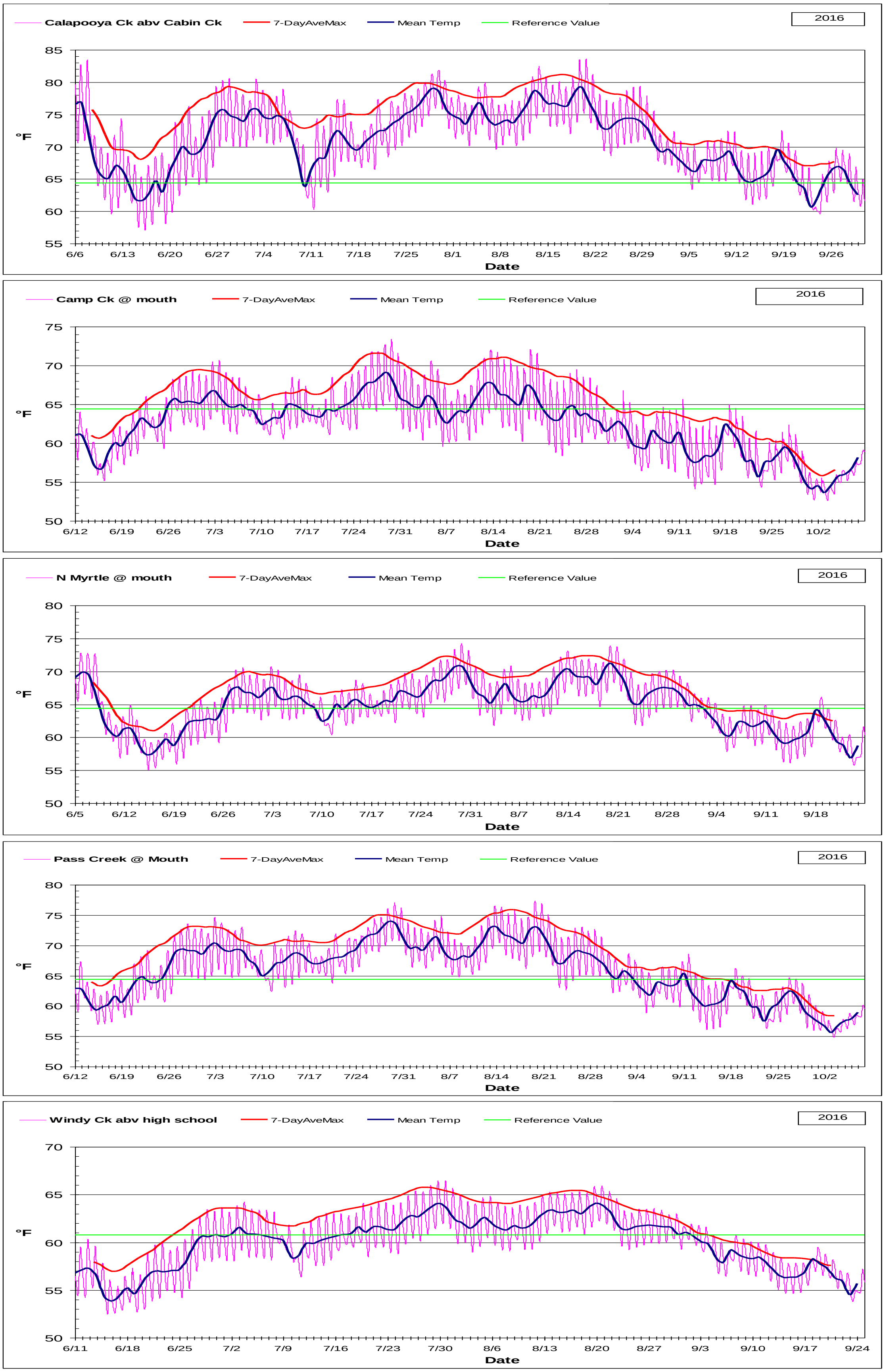

Figure 2. 2016 Umpqua Basin reference site stream temperature data measured at 30-minute intervals. The reference value is 64.4°F for all sites except Windy Creek which is 60.8°F (ODEQ 2003 & 2011).

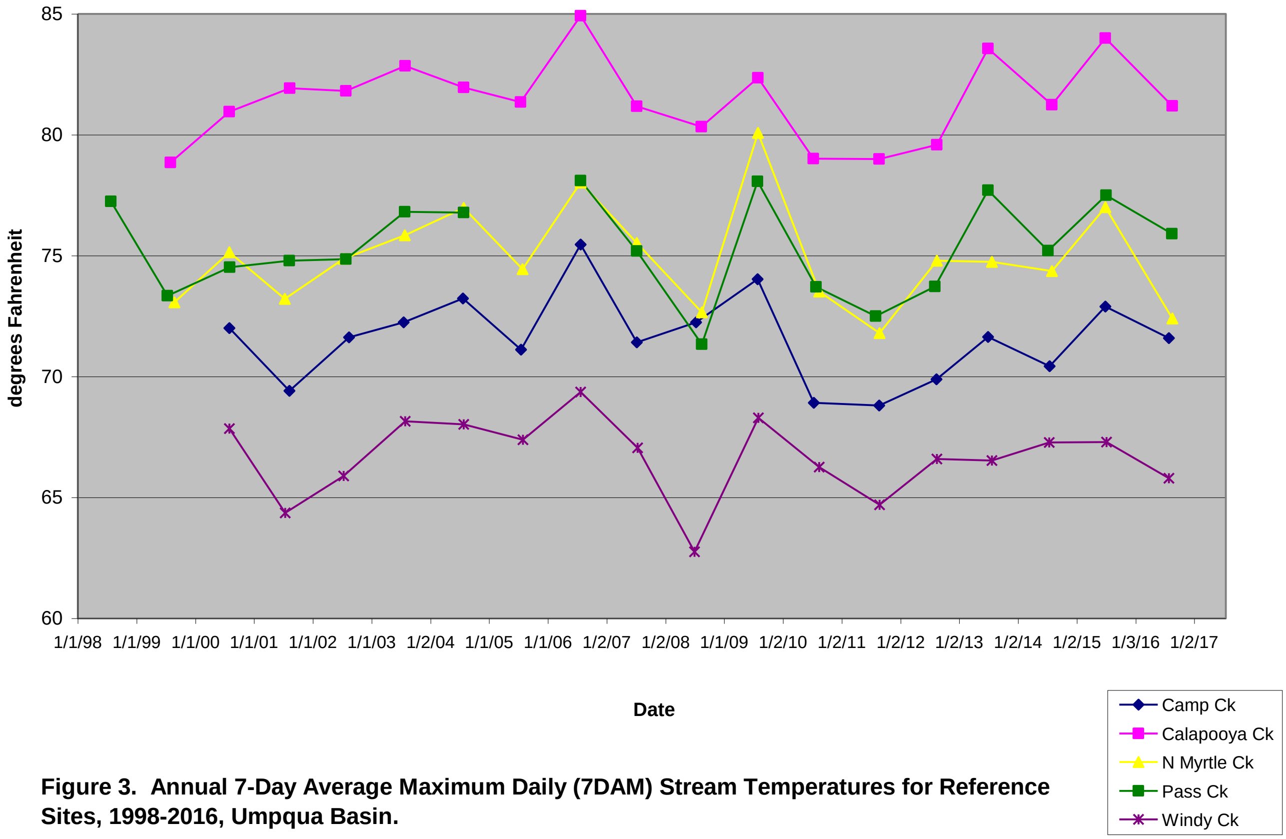

Figure 3. Annual 7-Day Average Maximum Daily (7DAM) Stream Temperatures for Reference Sites, 1998-2016, Umpqua Basin.

which is higher and which is lower, though last four years Pass has been higher (Figure 3). North Myrtle Creek did have a little lower 7DADM stream temperature than typical though as related to the other sites (Figure 3). Camp Creek has always had the second lowest 7DAM stream temperatures with the exception of in 2008 with no known explanation for the anomaly that year (Figure 3). In 2016, no sites had the highest or lowest 7DAM stream temperatures compared to the period of record, but most ranked somewhere in the middle, except North Myrtle Creek and Windy Creek which had the 2^{nd} and 4^{th} lowest 7DAM stream temperatures respectively (Figure 3 and Table 3). Interestingly, in 2015, which was the hottest year on record, the 7DAM stream temperatures were not the highest, but between the 2^{nd} and 4^{th} highest for all except Windy Creek which is the 7^{th} highest for the period of record (Dammann, 2015).

Since many of the factors affecting stream temperatures (surface area, flow, cloud cover, air temperature, and day length) vary daily and annually, this has resulted in annual variability in maximum stream temperatures. 7DAM stream temperature has varied annually as much as 6.06 to 8.28ºF depending on the site during the 17-18 year period of record (Figure 1 and Table 3).

As a stream flows from its headwaters, its temperature will continue to change, as a result of several factors including increased solar radiation (Beschta, *et al.*, 1987) and increased flow. The Calapooya Creek site is furthest from the ridgetop divide and has the highest 7DAM temperatures. Windy Creek is closest to the divide and has the lowest 7DAM temperatures (Table 3). Smith (2003) found that the cold limit line where the water temperatures typically exceed 64^{o}F is at 7 miles from the divide. The reference site data are consistent with that finding, except in 2008 at Windy Creek, which is 9.63 miles from the divide, when the 7DAM stream temperature dropped below 64^{o}F (Figure 3 and Table 3).

The approximate 6-8ºF temperature difference in 7DAM stream temperature for the reference sites during the period of record (Figure 3 and Table 3) indicates the importance of long-term monitoring or using another method (such as those discussed further below) to reduce the effects of annual variability, since it would be difficult to discern trends in the data from annual variability when using a data set with only a few years of stream temperature data. If climatic conditions are such that stream temperatures were warmer or cooler after a restoration project is completed without the use of reference data, it may appear that the restoration project was successful or unsuccessful in lowering stream temperatures which may be inaccurate. By using tools to correlate with the reference temperature data, project data can be normalized for annual variability. For instance, if a restoration project had post-project monitoring from 2009-2011, one may determine that the project was effective at reducing stream temperature; whereas streams throughout the basin had temperature reductions at that same time period (Figure 3) and only closer examination normalizing the data for annual variability can determine if stream temperatures were actually reduced. Similarly if post project monitoring was conducted from 2001-2003, a period when temperatures were increasing (Figure 3), one may determine that the project was not effective at reducing stream temperature, whereas normalization for annual variability using reference temperature data would give more insight into the actual trends.

Table 3. Umpqua Basin reference site highest, lowest, and difference in 7-day average maximum (7DAM) stream temperatures from 1998-2016 and distance from sites to ridgetop.

	Calapooya Ck	Camp Ck	N Myrtle Ck	Pass Ck	Windy Ck
Highest 7DAM temperature (°F)	84.92	75.46	80.08	78.10	69.36
Lowest 7DAM temperature (°F)	78.86	68.80	71.80	71.33	62.75
Difference in 7DAM temperatures (°F) (ΔT)	6.06	6.66	8.28	6.77	6.61
Distance from site to ridgetop divide (miles)	28.47	21.41	18.26	13.30	9.63
Drainage area (acres)	103,500	22,550	37,190	40,090	15,660
Ranking of 2016 Data	13th Highest	10th Highest	2nd Lowest	8th Highest	4th Lowest
Years of survey	18	17	18	18	17

Summer 2015 was the hottest summer on record for the three cities that surround the study sites; however, though they were among the hottest, they did not result in the hottest stream temperatures. The years 2014 and 2013 had the 2nd and 3rd hottest summers on record, but also did not have the hottest stream temperatures on record. Similarly, though 2014 had more days exceeding 90°F compared to 2015, but 7DAM stream temperatures were higher in 2015 compared to 2014 (Figure 3). The hottest stream temperatures in the last 18 years actually occurred in 2009 and 2006. In 2009, all five reference sites had the highest air temperatures July 28 and 29 (Dammann, 2009) which corresponds with record breaking air temperatures in the region (The Oregonian, July 29 and 30, 2009 and The News-Review, July 29 and 30, 2009). In 2006, four of the sites had their highest 7DAM stream temperature for the period of record of this study. In late July that year, there were the highest minimum air temperatures ever recorded (Taylor and Hale, 2006) which resulted in very high stream temperatures for the study sites due to the lack of nighttime cooling. These examples show how other factors than simply high daily air temperatures can influence the maximum stream temperatures, such as when the maximum air temperatures occur in conjunction with day length, the magnitude of the high maximum air temperatures, and minimum air temperatures. (Dammann, 2015)

Timing of 7DAM Stream Temperatures:

For the eighteen year period of record, the dates of the 7DAM stream temperatures have been between June 30 and August 26, but most commonly between late July and early August (Figure 4) which are times of long day lengths, high air temperatures, and decreasing flows (and consequently decreasing surface area). It's interesting to look at how the combination of these three characteristics: day length, air temperature, and flow and the annual variability in the temperatures and flow interrelate to determine the maximum stream temperatures, the date it occurs, and other patterns related to summer stream temperatures. A hot June with low flows could result in the 7DAM stream temperatures being earlier. A hot September with low stream flows could result in a September 7DAM stream temperature, but less likely given that day lengths are decreasing. In 2014, there were high temperatures in September; however, none of the 7DAM stream temperatures occurred during the September heat waves when stream flows were at the lowest, possibly due to the fact that shorter day lengths mean that the streams are heated for a shorter period of time each day than they are earlier in the summer closer to the solstice (Dammann, 2014).

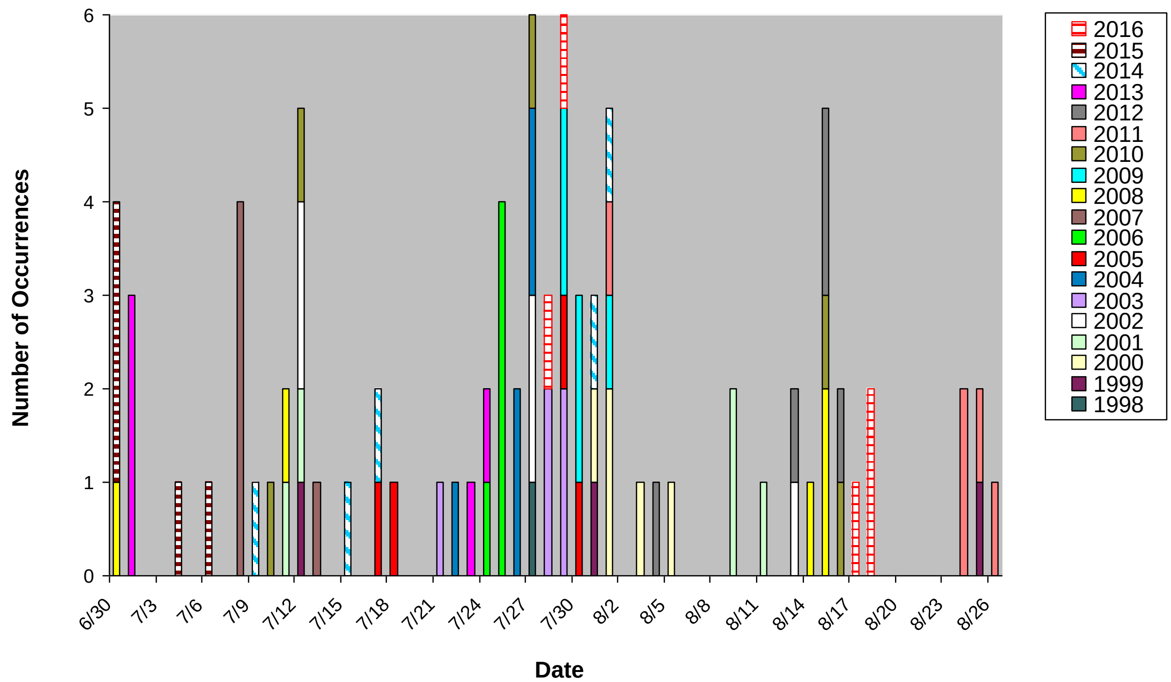

Figure 4: Dates of 7-day average maximum stream temperatures for the Umpqua Basin reference sites from 1998-2016.

Some years, air temperatures (either high daily temperatures or high nighttime temperatures) in a certain week have been the dominant factor affecting stream temperatures, resulting in the high temperatures for all five reference sites to be within a few days (Figure 2). This was the case in 2009 when all five reference sites had the highest air temperatures July 28 and 29 (Dammann, 2009) which corresponds with record breaking air temperatures in the region (The Oregonian, July 29 and 30, 2009 and The News-Review, July 29 and 30, 2009). In 2006, 7DAM stream temperatures were dominated by record breaking high minimum temperatures in late July (Taylor and Hale, 2006 and Dammann and Smith, 2006).

In 2016, the 7DAM stream temperature of Camp Creek occurred on July 28; Windy Creek occurred on July 29; Pass Creek occurred on August 17; and Calapooya and North Myrtle Creeks occurred on August 18 (Figure 4). All of these occurred during sustained heat waves.

Currently, there is a large bell curve in Figure 4 around July 22 – August 1 in the center, indicating a high concentration of 7DAM stream temperatures occurring during that time period. The graph shows possibly two bells around July 8-18 and August 9-16 and an increase from June 30 – July 1 as well. With more years of data, we will learn if a typical bell curve be established or if another pattern will emerge.

Effects of Hot Air Temperatures in Late May and Early June on 2016 7DAM Stream Temperatures:

As previously mentioned, in 2016, the reference temperature sites had summer stream temperature data beginning on June 5 (North Myrtle Creek), June 6 (Calapooya Creek), June 11 (Windy Creek), and June 12 (Camp and Pass Creeks). In late May and early June 2016 there were very low stream flows and high air temperatures. In Roseburg, from May 31 to June 7, maximum air temperatures were, 89^{o}F, 89^{o}F, 85^{o}F, 89^{o}F, 97^{o}F, 97^{o}F, 96^{o}F, and 96^{o}F (NWS, 2016). It would be highly unlikely that the 7DAM stream temperatures would be earlier than the summer solstice given that flows are usually decreasing at this time, but given these extremely high early summer air temperatures, long day lengths, and low flows, there was a stronger likelihood in 2016 than in other years.

Roseburg District BLM, Umpqua National Forest, and PUR all had water temperature recorders out in small streams (of similar size to the reference temperature sites) throughout the Umpqua Basin in May or the beginning of June. These sites were Deer near Mouth (PUR), North Fork Deer near Mouth (PUR), South Fork Deer near Mouth (PUR), Newton Creek (PUR), Roberts Creek near Mouth (PUR), Bear Creek (BLM), Yellow Creek above Bear (BLM), Big Tom Folley Lower (BLM), Rock Creek above East Fork (BLM), Coyote Creek Watershed #4 (USFS), Drew Creek (USFS), Dumont Creek (USFS). Out of these 12 sites, only one, PUR's North Fork Deer near the Mouth, had the 7DAM stream temperature during the early June heat wave (on June 5^{th} which was also the seasonal maximum stream temperature date). Drew Creek had the seasonal maximum stream temperature in early June, but not the 7DAM stream temperature. While the BLM and USFS sites were year-round, the PUR sites data set began on June 2. Since the PUR sites are lacking the early part of the heat wave, the possibility exists that these data sets may have missed the 7DAM stream temperature, however, since the maximum stream temperatures for the PUR sites were not in early June (unlike with North Fork Deer), it is less likely than if the maximum did occur in early June. The lesson learned here is that while 7DAM stream temperatures are unlikely to occur in early June, under very low flows and very high stream temperatures they can. Also note that the PUR data is preliminary as the water temperature recorders have not had their end of the season quality control checks.

Stream Temperature Variability Holding Day Length Constant:

As previously stated, the highest stream temperatures are typically between mid-July and mid-August when temperatures are usually high and flows are decreasing (Figure 2). Since the solar position is the same on any given day for each year, in order to hold day-length constant, the temperatures on August 1 at 4pm (typically the hottest time of the day) is graphed for each year and site (Figure 5). August 1, 4pm temperatures (Figure 5) show a similar pattern as the 7DAM stream temperatures (Figure 3), with Calapooya Creek being the highest each year (except in 2009, when North Myrtle Creek was warmer) and Windy Creek the lowest (except in 2010 when Camp Creek was 0.3°F cooler), with North Myrtle and Pass Creek having similar temperatures varying year to year, and Camp Creek being the second lowest except recently (Figure 5). In 2015 and 2016, North Myrtle Creek had lower temperatures as compared to other sites than previous years (Figure 5). We will see if that pattern continues into the future. Since day length is held constant in this graph, the pattern shows the significance of solar output and flow volume in the temperature pattern throughout the basin. It also demonstrates the difference between using actual data instead of statistics (such as 7DAM stream temperatures).

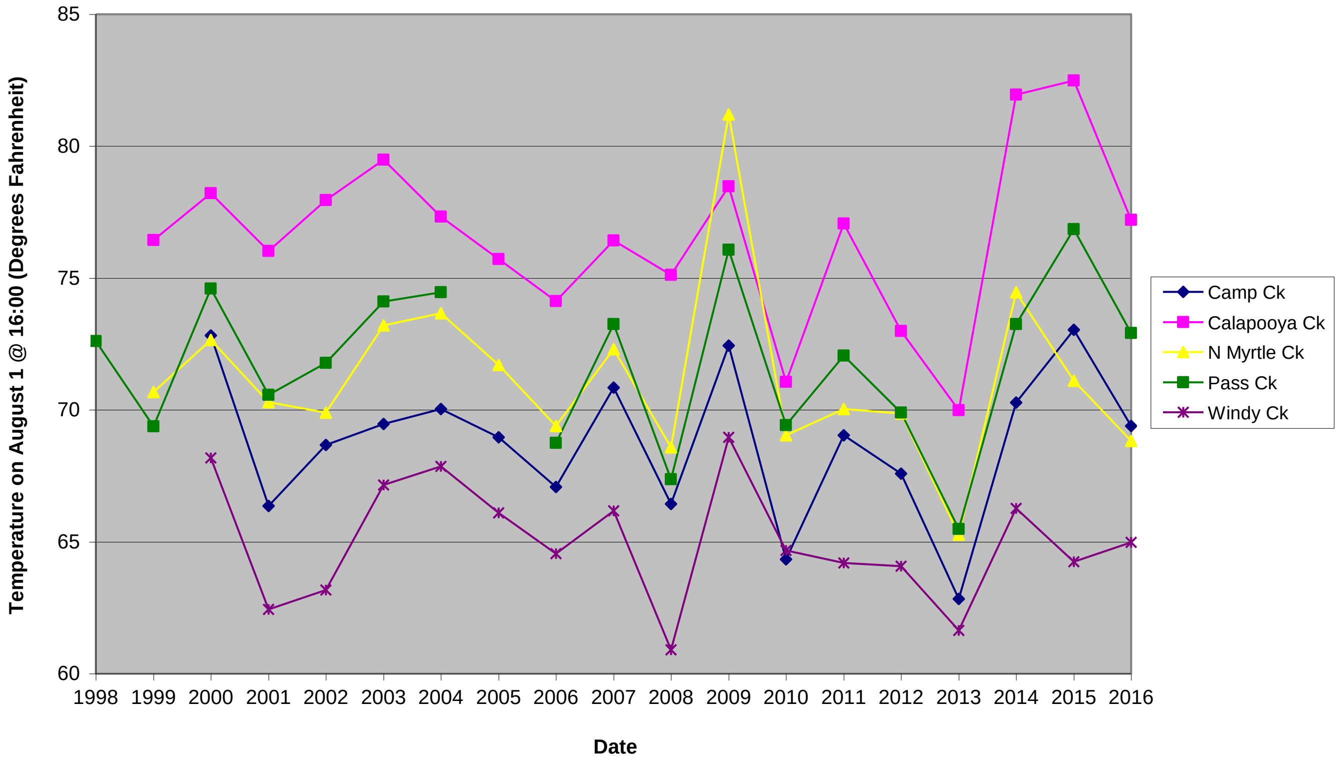

Figure 5. Umpqua Basin reference site stream temperatures on August 1 at 16:00 from 1998-2016.

Stream Temperature Relative to Flows at North Myrtle, Pass, and Windy Creeks:

Flows have been collected during the summer at North Myrtle, Pass, and Windy Creek reference sites by Oregon Water Resources Department (OWRD) since 2004 and at Calapooya and Camp Creeks since 2010 (UBWC {later renamed PUR} 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, and 2013; PUR 2014, 2015, and 2016). (In 2011, flows at Calapooya Creek were taken approximately ¼ mile downstream due to access issues, there is a very small stream entering between the two sites, but it should have a minimal effect on the flow.) The linear regressions of the flow data at the North Myrtle, Pass, and Windy Creek indicate varying strengths of negative linear correlation between flow and 7DAM stream temperature at these sites.

At North Myrtle Creek (r^2=0.1052) and Pass Creek (r^2=0.0857) sites, there are very weak negative correlations between 7DAM stream temperatures and flow (Figure 6). However, for Pass Creek, if the outlier at very low temperatures and flow were removed, the r^2=0.5233, which is a strong negative correlation (Figure 6). It appears that flow and 7DAM stream temperatures are negatively correlated at

Pass Creek, except in the situation with the outlier when there was a very low flow and very low stream temperatures possibly due to hyporheic flow at the low flows (Figure 6).

Data also indicates a negative correlation between flow and 7DAM stream temperature at Windy Creek (r^2= 0.3228) (Figure 6). However, the highest 7DAM stream temperature of record at Windy Creek occurred in 2006 (Figure 3). This point is an outlier when compared to the flow occurring at the time (3.46 cfs) (Figure 6) and if removed the r^2=0.7797 (Figure 6), which is a very strong negative correlation and indicates that the negative correlation between 7DAM stream temperatures and flow at Windy Creek does not apply when there are very warm stream temperatures. Perhaps high air temperatures resulted in increased stream temperature that overshadowed the effects of hyporheic flow resulting in high stream temperatures.

Flow data collection at Calapooya and Camp Creeks began midsummer in 2010. However, the 7DAM stream temperature occurred early in the summer and flows had not yet been collected, so there is no data available to compare 7DAM stream temperature with flows that year. Also, at Calapooya Creek in 2015, flow data was not collected early enough to have data at the time of the 7DAM stream temperature as well. With only four and six years of data respectively, it is difficult to ascertain any trend; however, the linear regressions indicate that there is at most a very weak correlation between flow and 7DAM stream temperature at Calapooya Creek (r^2=0.0006) and a weak correlation at Camp Creek (r^2= 0.1678) (Figure 6). More data in future years will indicate if there is a correlation at these sites or not and provide more insight into all five sites.

The Effect of Air Temperature and Flows on Stream Temperature:

Since 2010, the summer flows at the five reference sites have been compared with maximum daily air temperatures and maximum daily stream temperatures. Figure 7 shows the 2016 comparisons and the 2010-2015 can be found in Appendix 1 (located on the Reference Temperature CD). In each stream, the trends in the water temperature reflect those in the air temperature (Figure 7), showing how stream temperature is partially dependent on air temperature. Furthermore, from 2010-2015 at Camp Creek, Pass Creek, and Windy Creek, as flow was decreasing, the stream temperatures still reflected the changes in the air temperature, but they were also overall slowly decreasing as the flow decreased throughout the season (Figure 7, Appendix 1, and Dammann, 2010, 2011, 2012, 2013, 2014, and 2015). This is likely due to hyporheic flow, decreased day lengths, or a combined effect of the two. The cooler hyporheic flow was a larger percentage of the flow when flows were decreased, thus decreasing the stream temperature. In 2016, the pattern is not as evident until September because maximum air temperatures were decreasing overall throughout late summer, but is still present.

In Calapooya Creek, the same relationship between air temperature, stream temperature, and flow was also evident, but not as noticeable in 2010 as it was the following four years (Figure 7 and Dammann, 2010, 2011, 2012, 2013 and 2014). In 2015 and 2016, the pattern was not as evident because maximum air temperatures were cooler overall in late summer than earlier in the summer and there was similar or increased flow (Figure 7, Appendix 1, and Dammann, 2015).

In North Myrtle Creek, in 2010 the stream temperature increased as flow decreased, perhaps due to less gravel substrate and less hyporheic flow at the site or more water withdrawals (Dammann, 2010); however, in 2011 and 2012, North Myrtle Creek's stream temperature was not clearly increasing or decreasing as flows decreased late in the summer (Dammann, 2011 and 2012); but in 2013-2016 they seemed to decrease as flow and day length decreased (Figure 7, Appendix 1, and Dammann, 2013, 2014, 2015).

A recent study of unregulated streams in the Western Continental United States, containing streams with comparable drainage areas and elevations as our study streams, found that from 1950-2010, the timing of minimum stream flows became earlier, while the timing of maximum stream temperatures has not changed (Arismendi, et al., 2013). This has resulted in a decrease in the time between the two biggest summer stresses to fish, maximum stream temperatures and the minimum stream flows (Arismendi, et al., 2013). The responses of high temperatures and low flows on aquatic organisms have been studied separately, but there's only limited data on the combined effect of the two (Arismendi, et al., 2013 and Clews, et al., 2010). As more years of data are collected at the reference temperature study streams, it will be interesting to observe the relationship between stream flow and stream temperatures and the timing of the two which could give more insight into how air temperature and flow affect stream temperature. There are many ways to analyze this long term dataset depending on future needs.

Examples of How Reference Temperature Data Is Used to Enhance Other Project Level Stream Temperature Site Data:

Often times with project level monitoring data, there are short data sets that only encompass a few years. With limited data sets, it's difficult to tell if a change in temperature from year to year is a response to work that has been done in a watershed or annual variability. The stream temperature records from these reference temperature sites can be used as a model to account for annual variability in other streams lacking that long-term data. There are several ways that one could use this reference temperature data to compare to other sites. One way, mentioned above, is to use the Ratio method (Smith, 2001b) which uses the ratios of the data from a study site to a reference temperature site in order to calculate a theoretical temperature for years with no data. Another is to use synoptic temperature data method (Smith, 2010) which utilizes ratios of statistics. Various visual comparisons, such as those described below, could be used as well.

Figure 8, from Lyon, Smith and Dammann (2012), shows an example of a way to use the data. In this instance, the North Myrtle Creek (at the mouth) reference temperature site, is one of only three data sets in North Myrtle Creek with a complete record and given that it is at the confluence, it is very useful for comparison to the other sites.

Figure 9 shows another method of visual comparison to utilize that data. At the Wolf Creek Restoration Site #10, a weir was constructed and gravel was added to the site. Three water temperature recorders were placed upstream of the weir and three were placed downstream of the weir. During the period of maximum stream temperature, most of the locations had diurnal peaks, like the reference temperature data (Figure 9). However, during the period of low flows, the trend differed; all of the Wolf Creek #10 sites had diminished mid-day stream temperature peaks compared with the reference temperature sites possibly due to hyporheic flow through the gravels (Figure 9).

At the Wolf Creek Restoration Site #9, a weir was constructed, but no gravel was added. Trends are similar to that of Site #10 with the exception that there's no differentiation in the upstream and downstream temperature data since there's no gravels cooling the water upstream of the weir (Figure 9). Having the reference temperature data for comparison gives the ability to better describe the trends in the Wolf Creek project data since the reference sites do not show the same diminished diurnal peaks during the low flows.

Oregon State Temperature Criteria:

Under the Oregon State temperature criteria, the 7DAM stream temperature for streams designated as core cold-water habitat may not exceed 60.8^{o}F (16.0^{o}C) and streams designated as salmon and trout rearing and migration areas may not exceed 64.4^{o}F (18.0^{o}C) (ODEQ, 2006 and ODEQ, 2011). Calapooya, Camp, North Myrtle, and Pass Creeks are all designated as salmon and trout rearing and migration fish use (64.4^{o}F threshold) and Windy Creek is designated as core cold-water habitat (60.8^{o}F threshold) (ODEQ, 2003). Figure 2 shows the daily summer stream temperature fluctuation for the reference sites in 2016, with the reference value line drawn at the ODEQ threshold for each stream. All streams exceeded the ODEQ criteria for every year at every site (Figure 3).

Acknowledgements:

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How to Obtain the 2016 Update CD:

All previous reports, data, and photos for the length of this project are located on the Umpqua Basin Stream Temperature 2016 Update CD. In addition, the Getdata program, found on the CD, allows the user to retrieve several statistics and graphs from the temperature data files. The Umpqua Basin Stream Temperature Update 2016 CD can be obtained from Denise Dammann Consulting or PUR.

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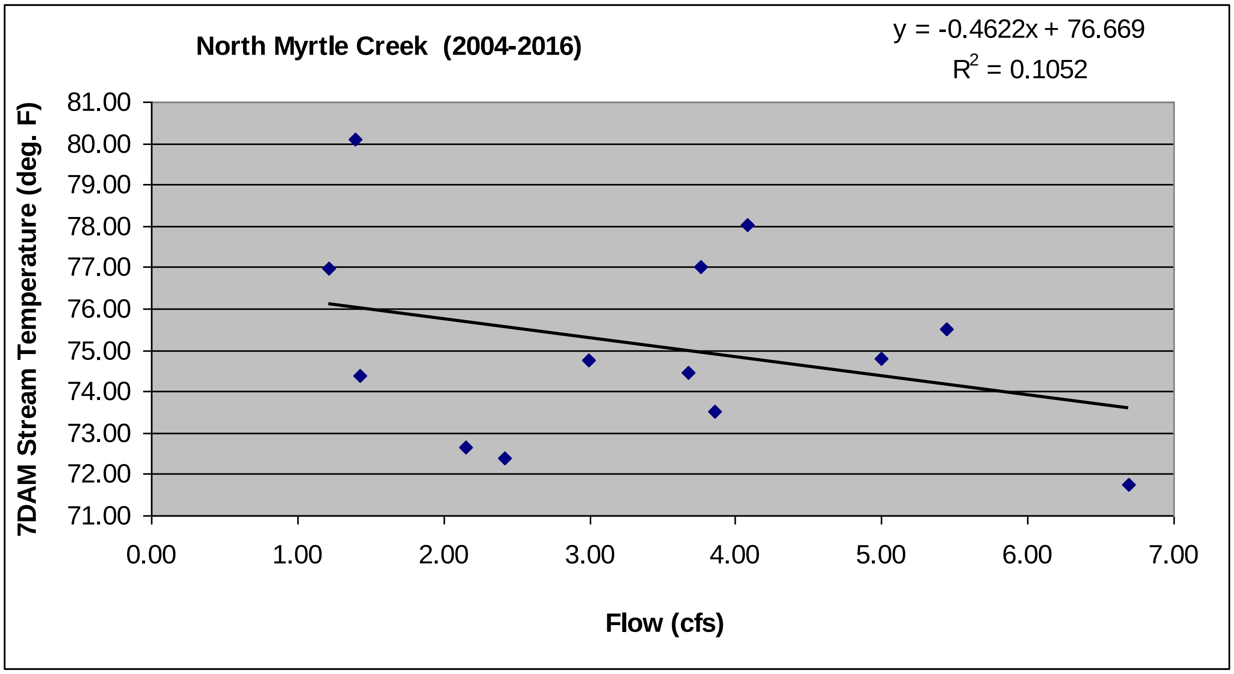
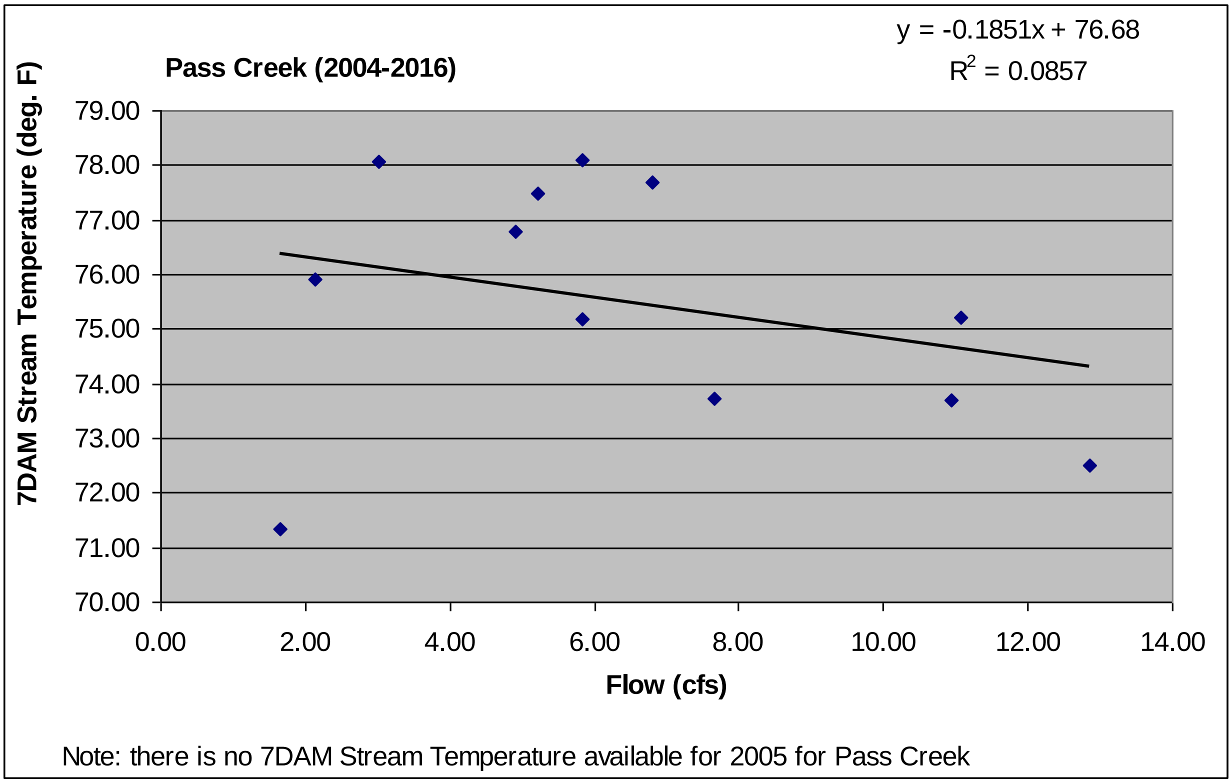
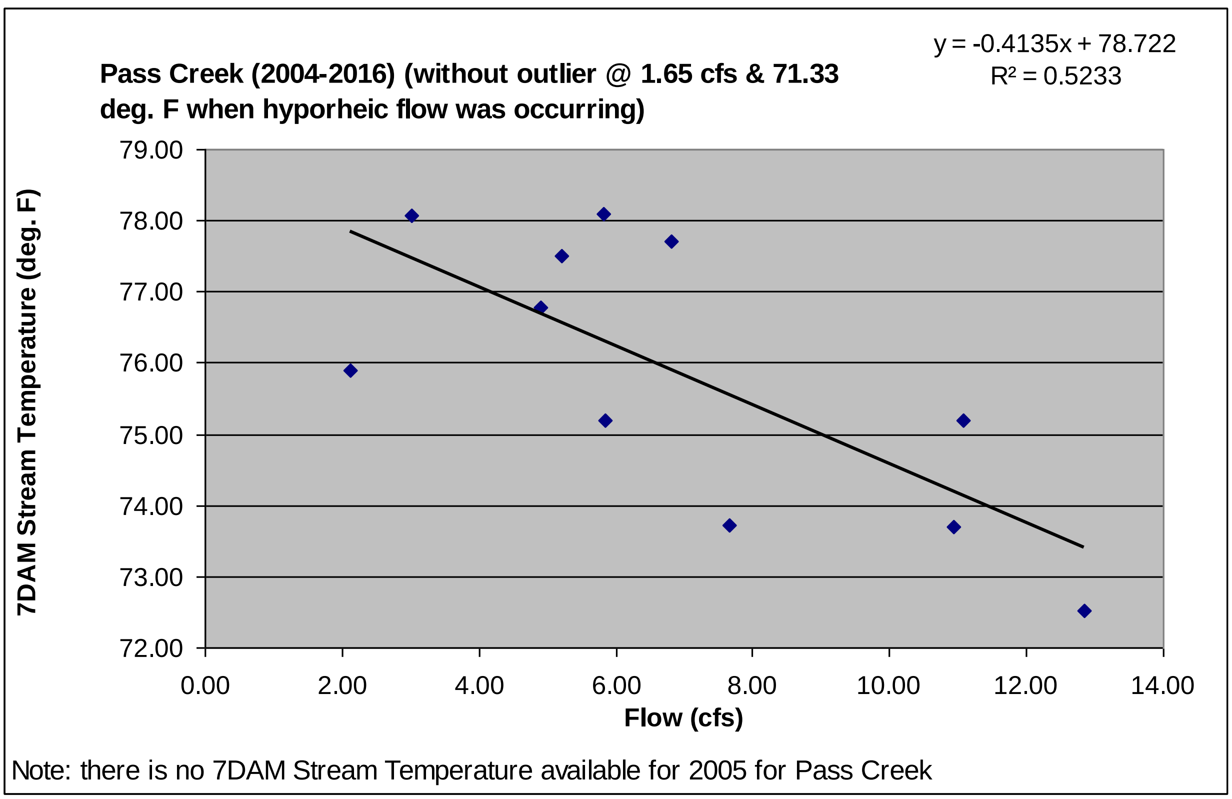


Figure 6. 2004-2016 Reference site 7DAM stream temperatures compared to flows on that day. Stream flows from OWRD (Umpqua Basin Watershed Council {PUR}, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, and 2013; PUR, 2014, 2015, and 2016). (Page 1 of 4)





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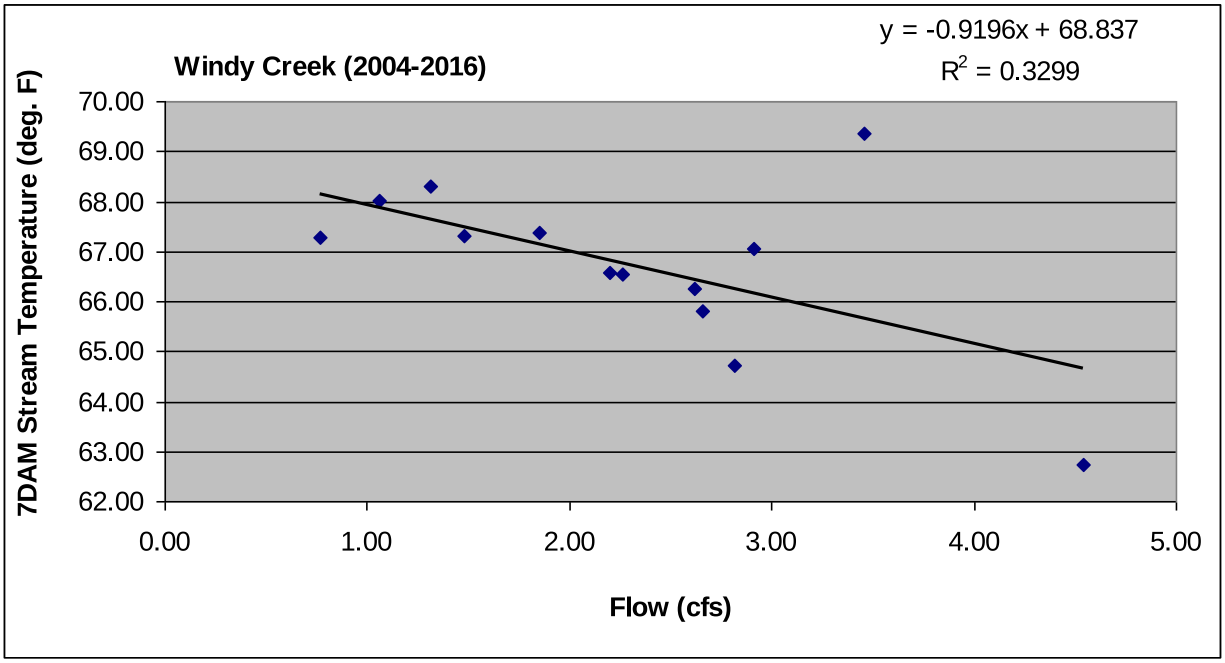

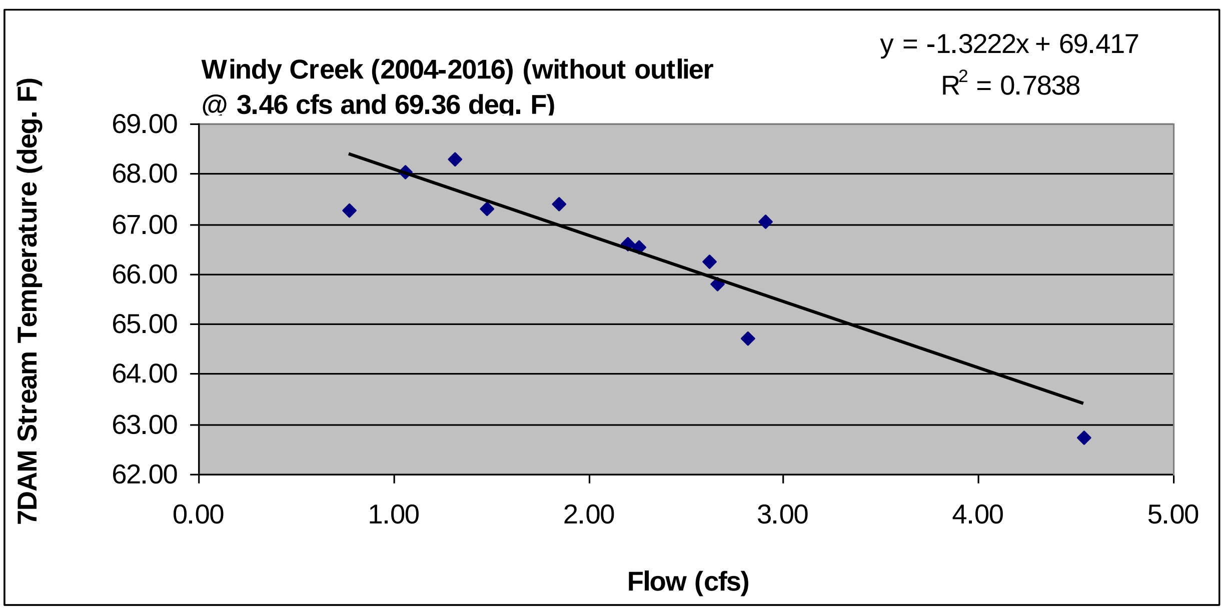

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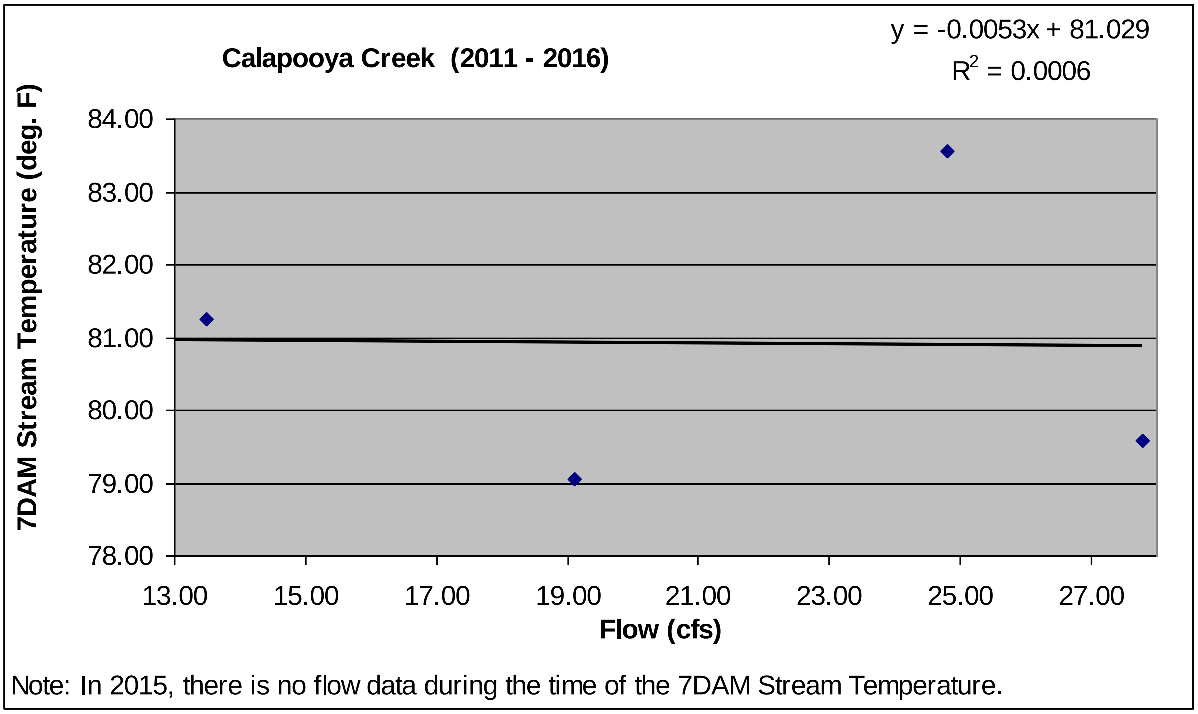

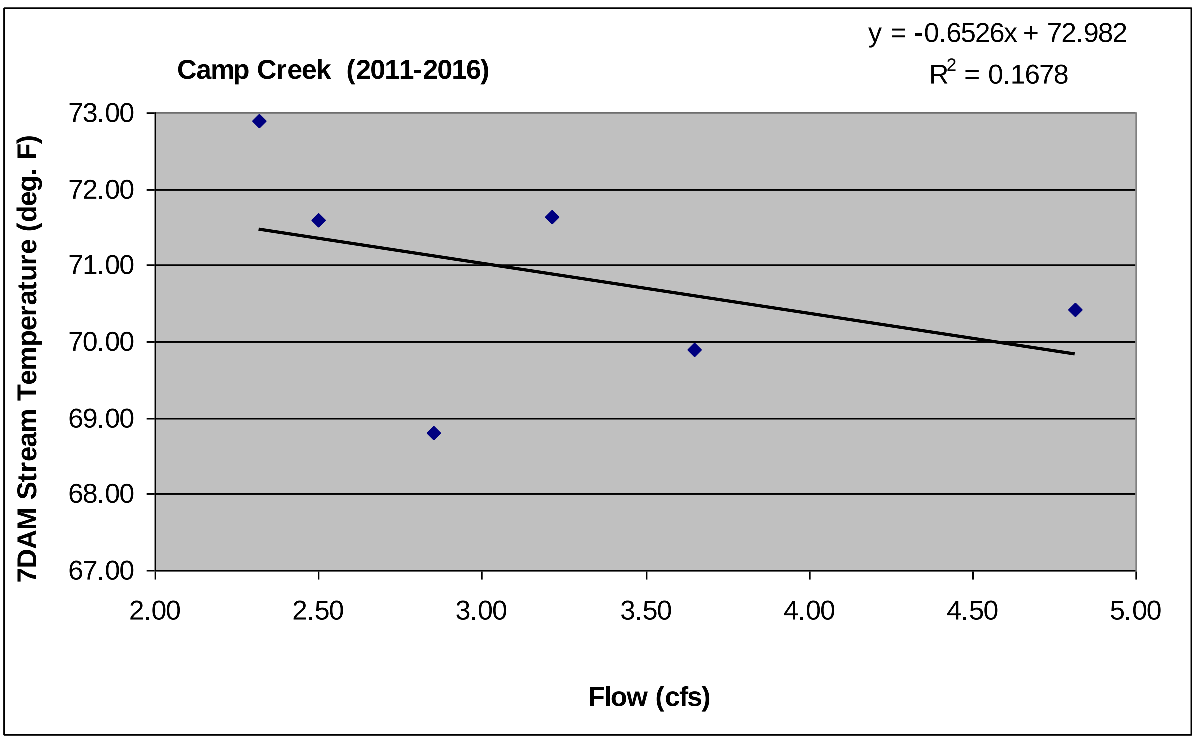

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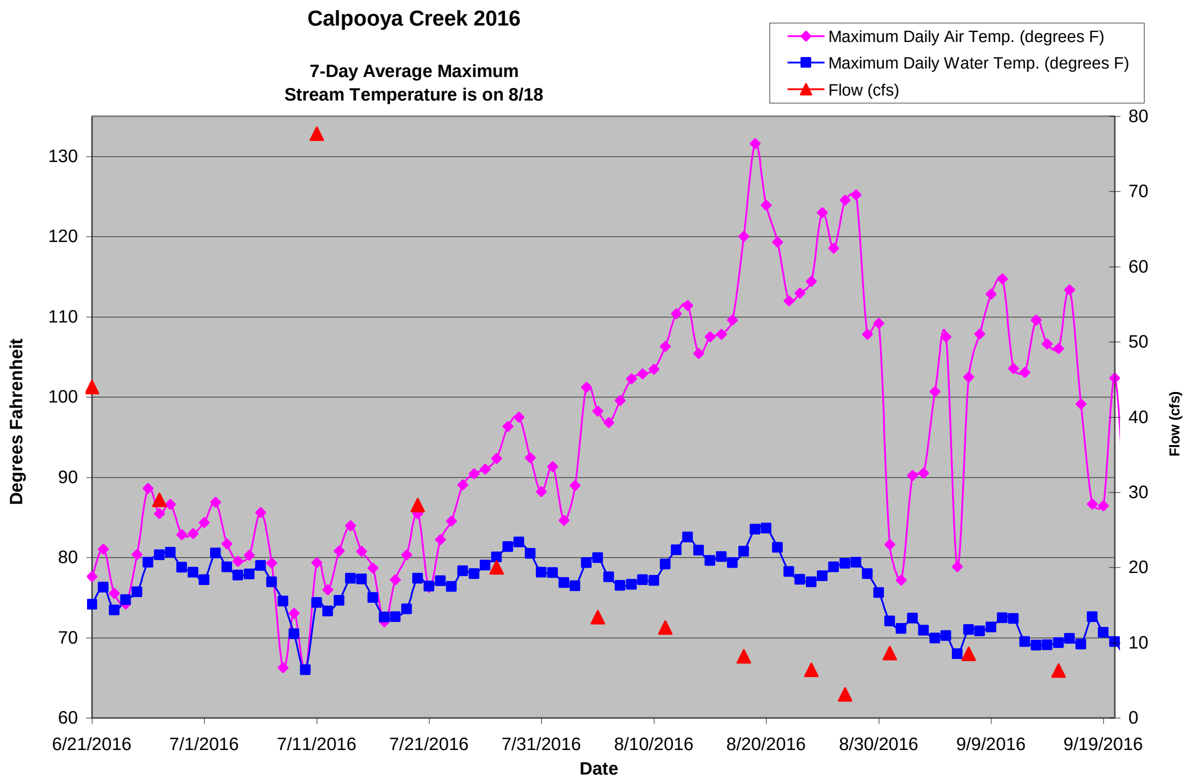


Extremely high air temperatures are due to temperature logger becoming uncovered mid-August and exposed to the daytime sun.

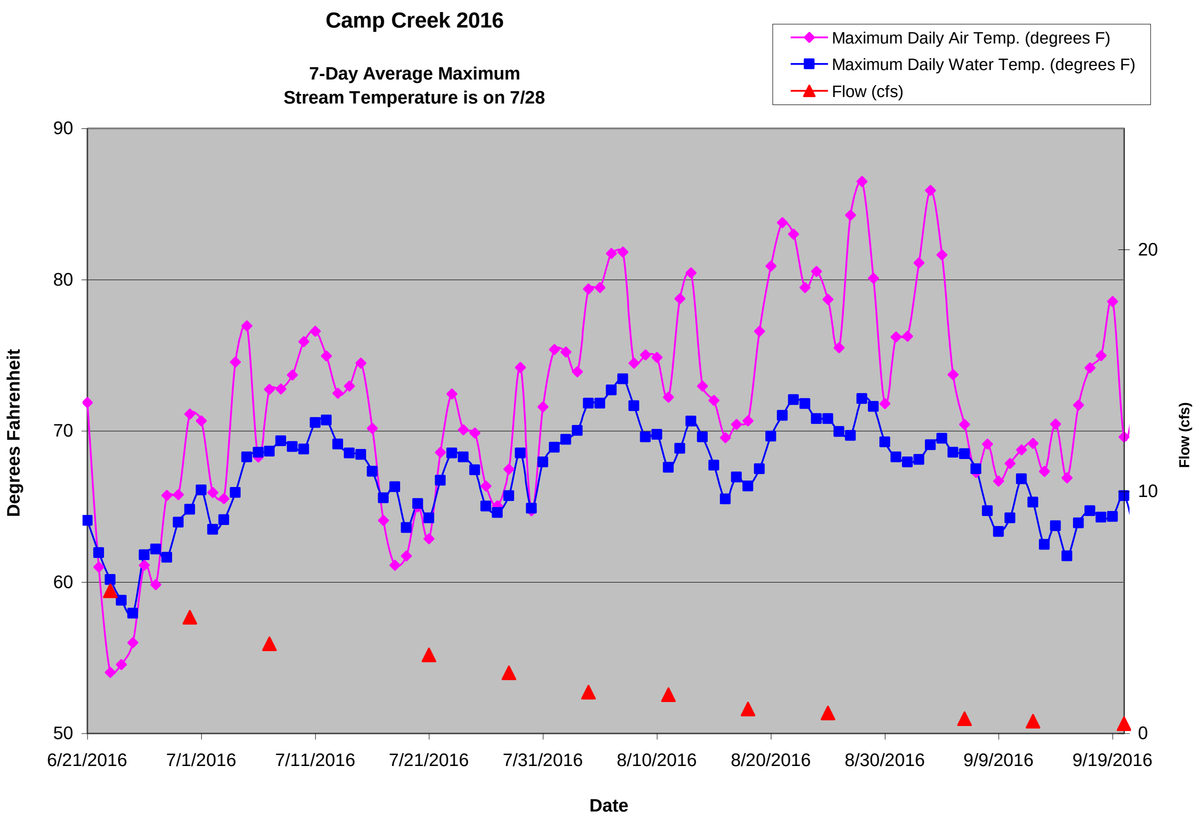
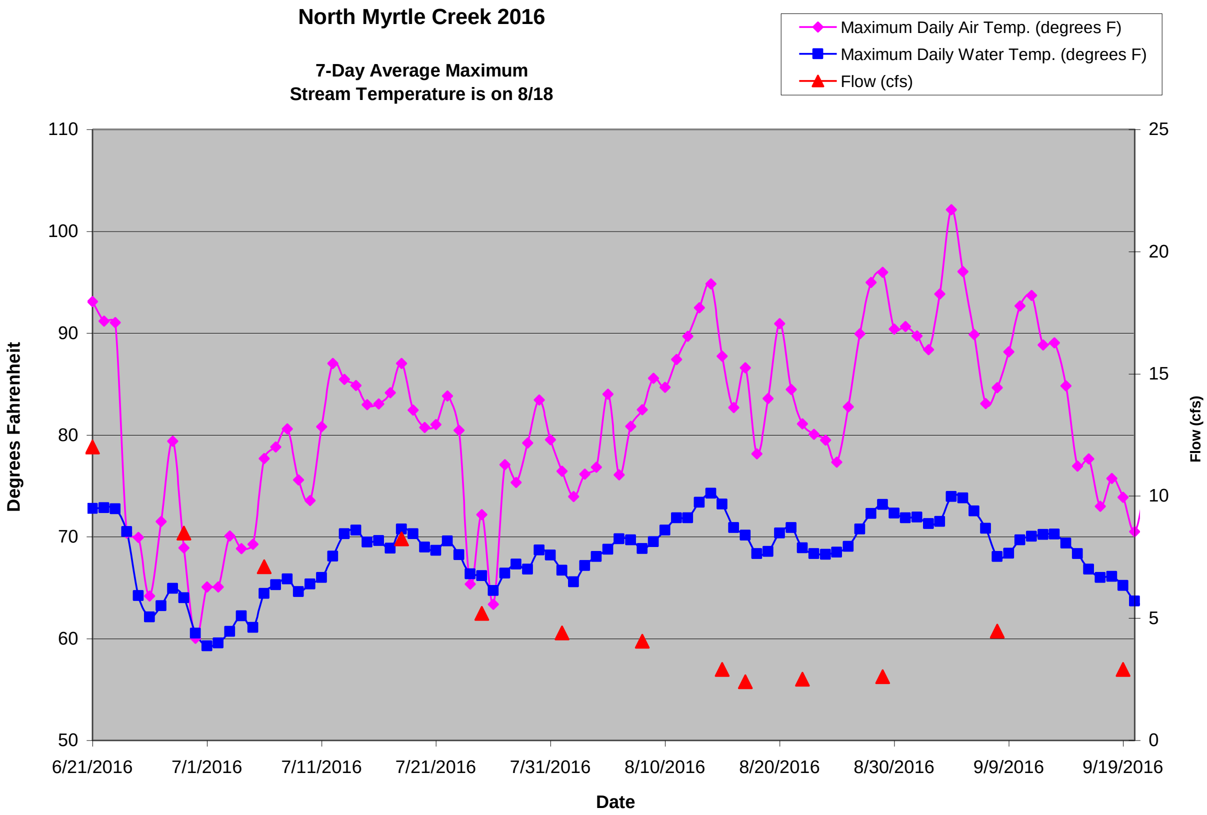
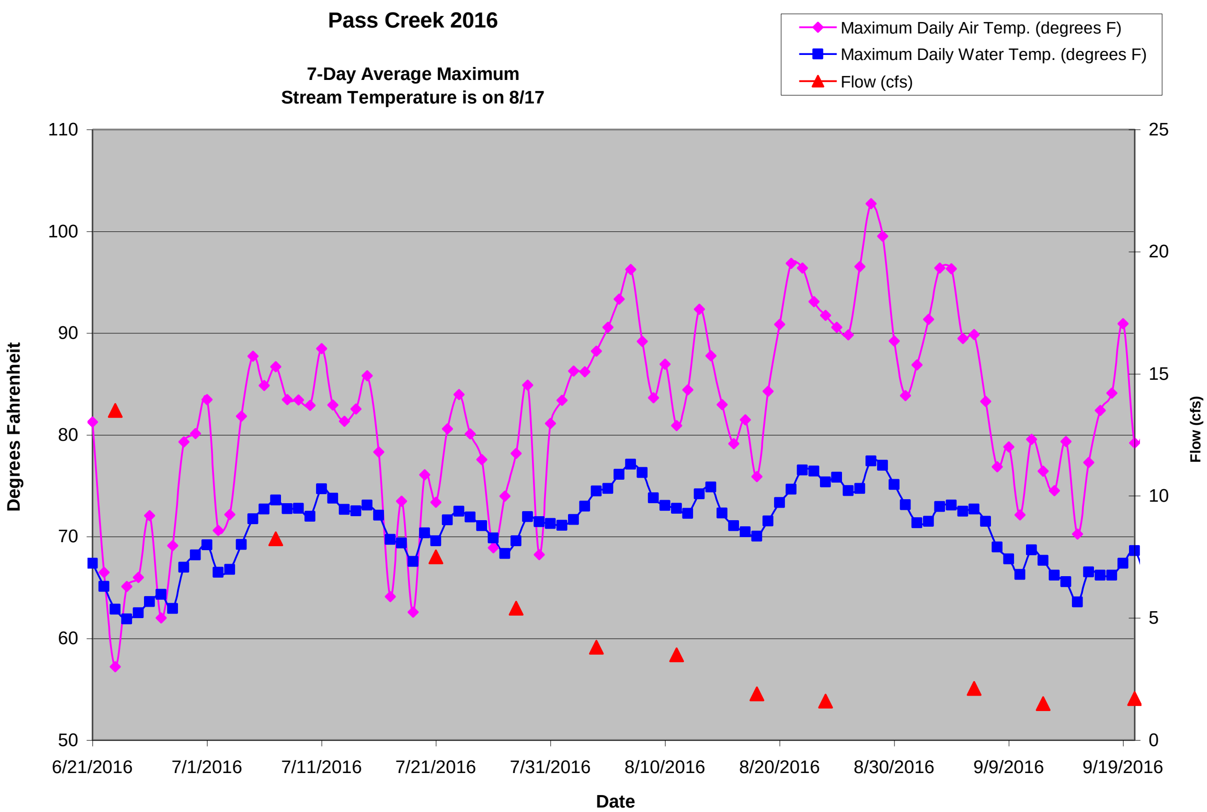


Figure 7. Maximum daily air temperature and flow compared to maximum daily stream temperature for the five reference sites for 2016. Note the high air temperatures for Calapooya Creek beginning mid-August; the equipment was found at the end of the season uncovered and exposed to the daytime sun, so it probably became uncovered in mid-August. (Page 1 of 3)





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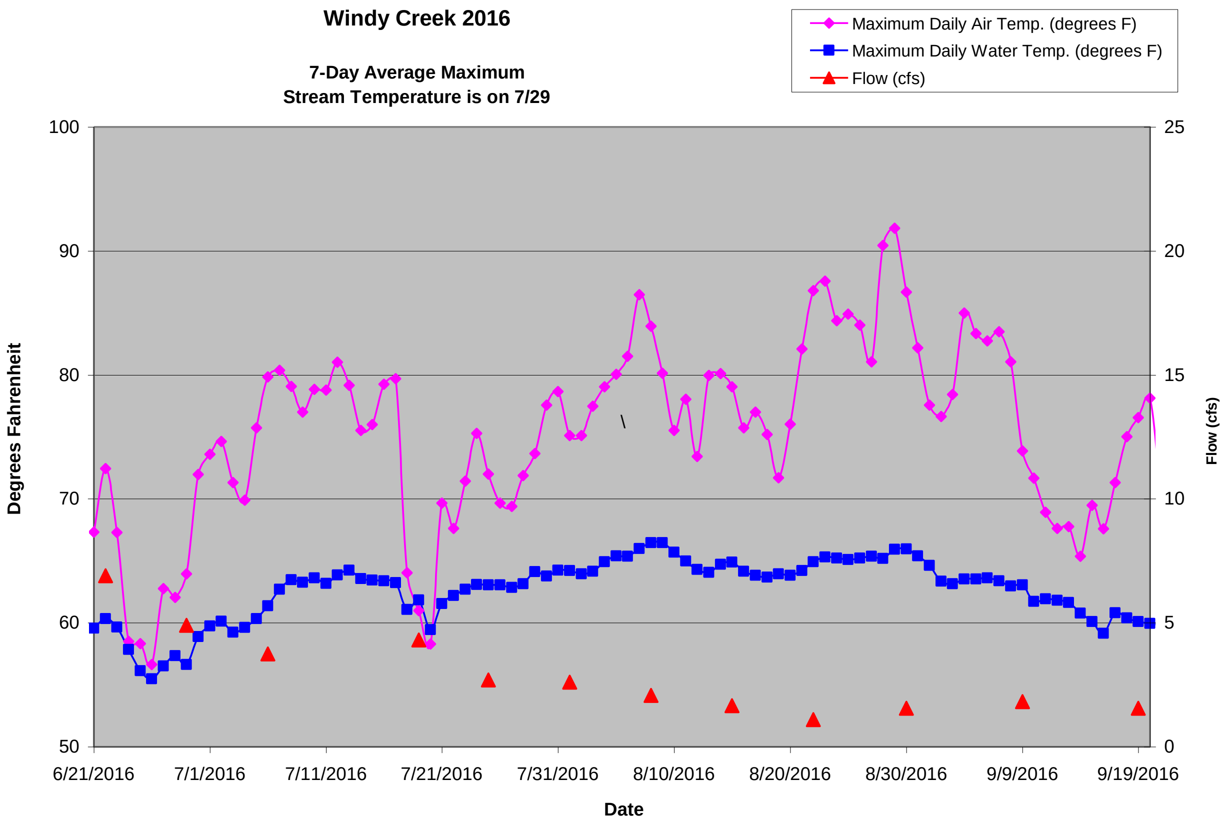

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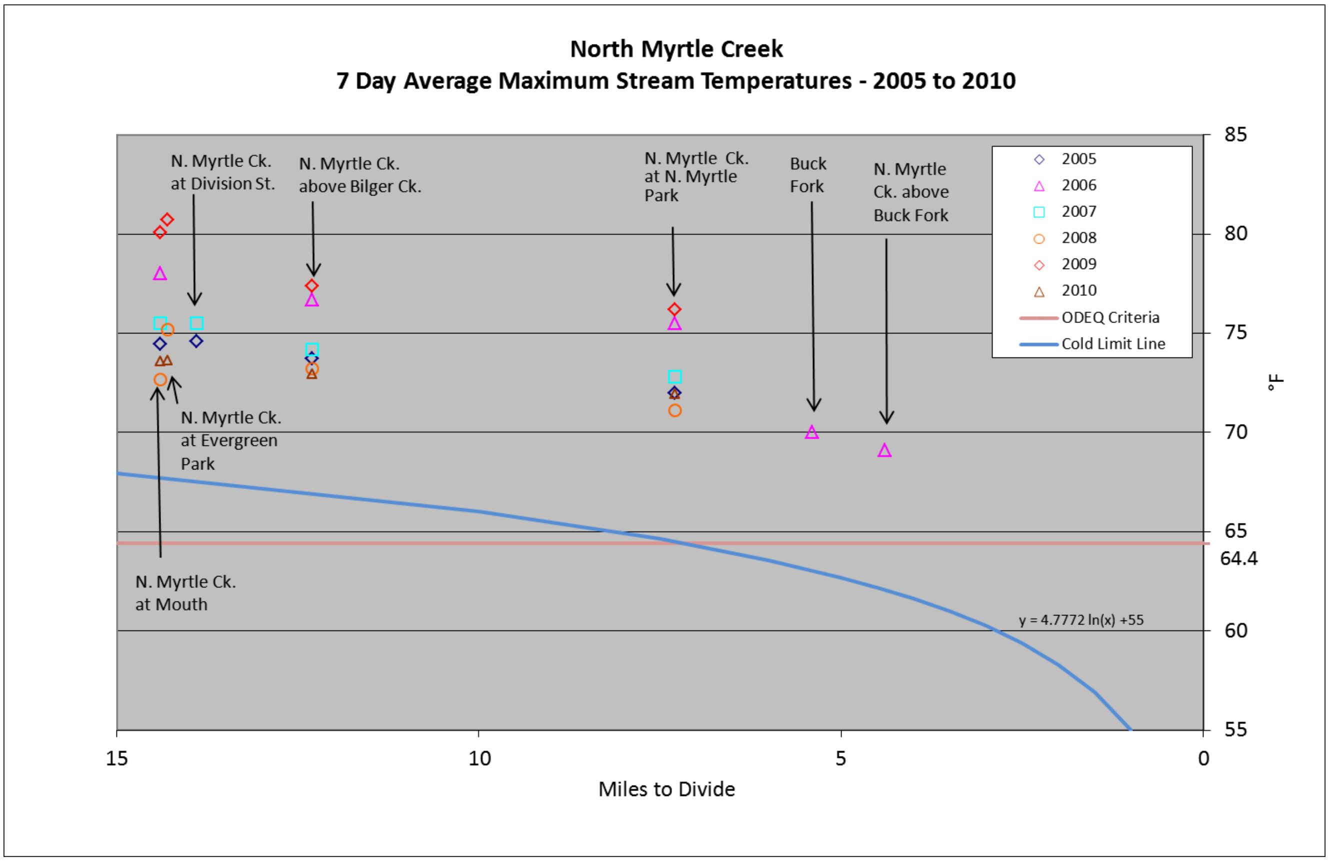
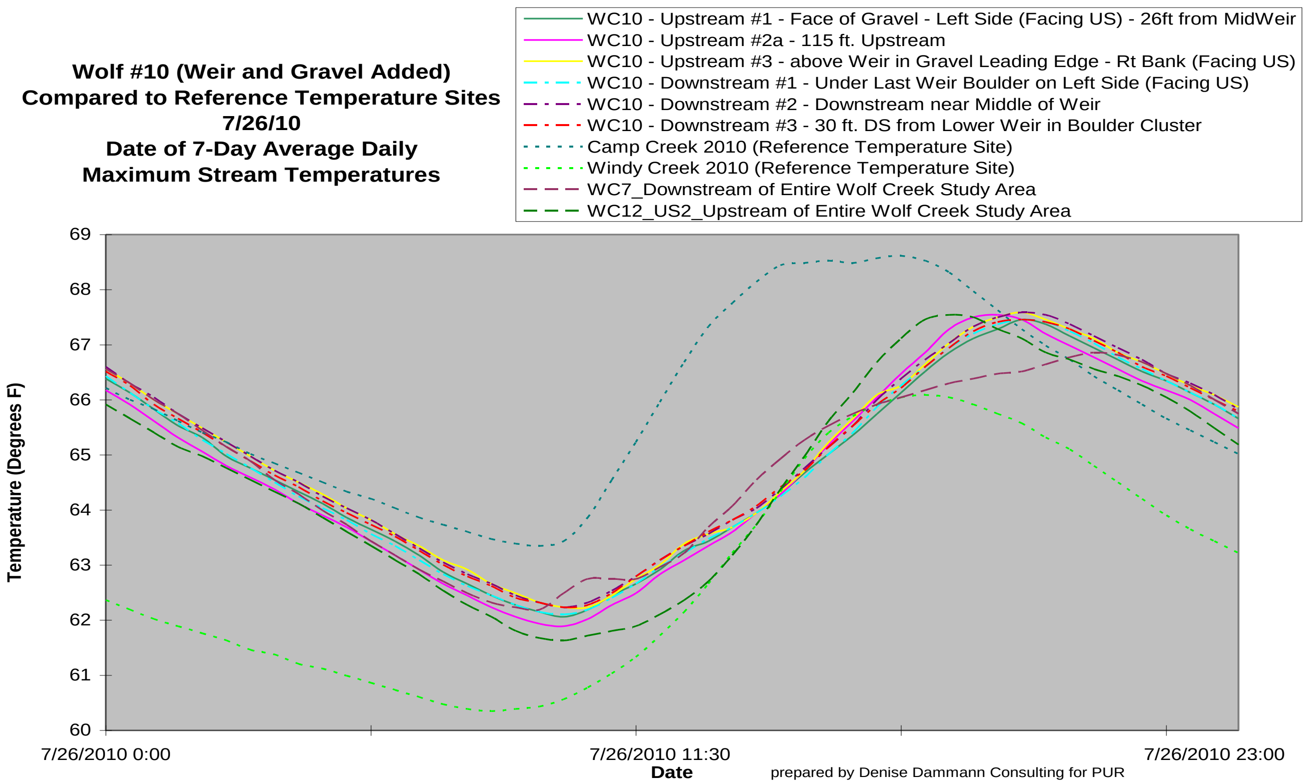


Figure 8. An example of using the North Myrtle Creek reference temperature site data for comparing to other sites in the basin, from Lyon, Smith, and Dammann (2012): North Myrtle Creek 7-day average maximum stream temperatures from 2005-2010 and corresponding land use map. Buck Fork is included since it has a similar distance to divide, drainage area, and flow as North Myrtle Creek at the confluence. The temperature criteria for streams in the Myrtle Creek area, which is designated salmon and trout rearing and migration use, is 64.4°F (ODEQ, 2003) and (ODEQ, 2011). The cold limit line represents the optimal stream temperatures for streams in the South Umpqua sub-basin as distance to the ridgeline divide increases (Smith, 2003). The North Myrtle Creek (at the mouth) Reference Site is a long-term stream characterization monitoring site (Smith, 2005), (Dammann and Smith, 2006), (Dammann, 2007, 2008, 2009, and 2010).



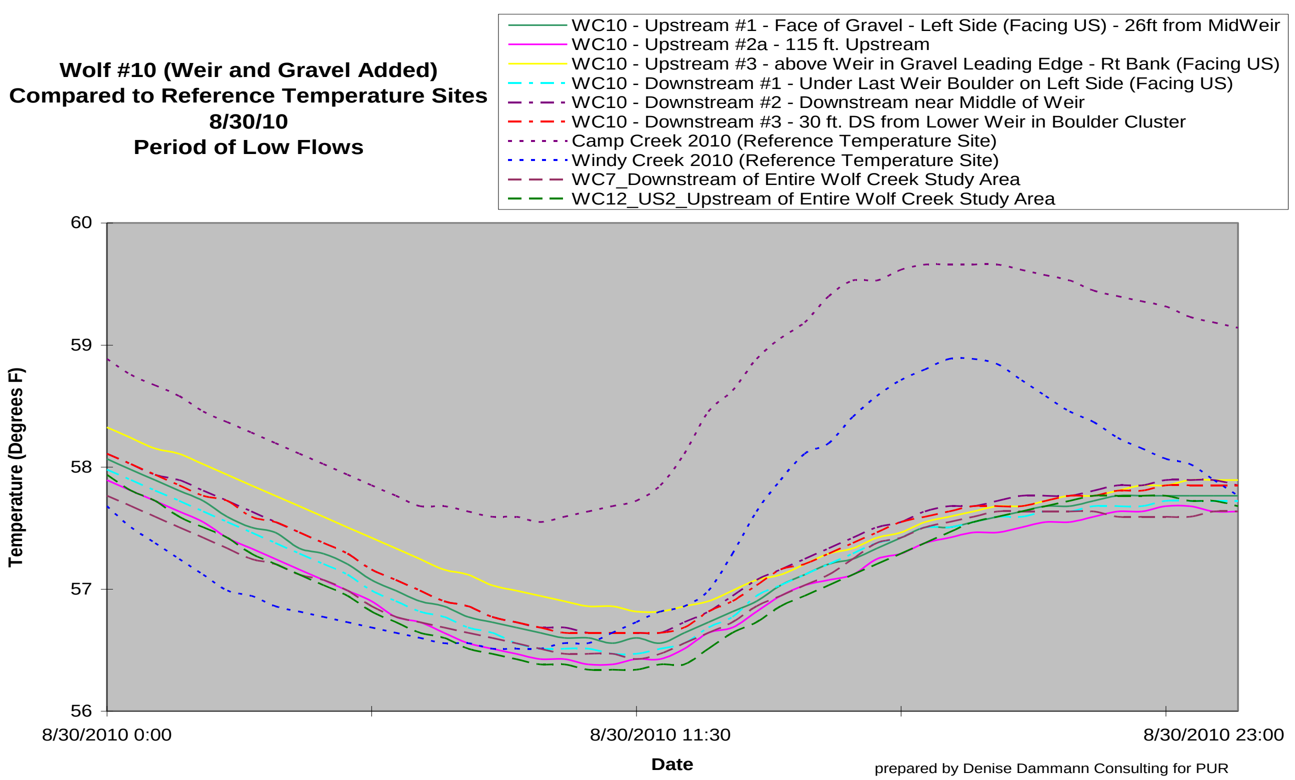
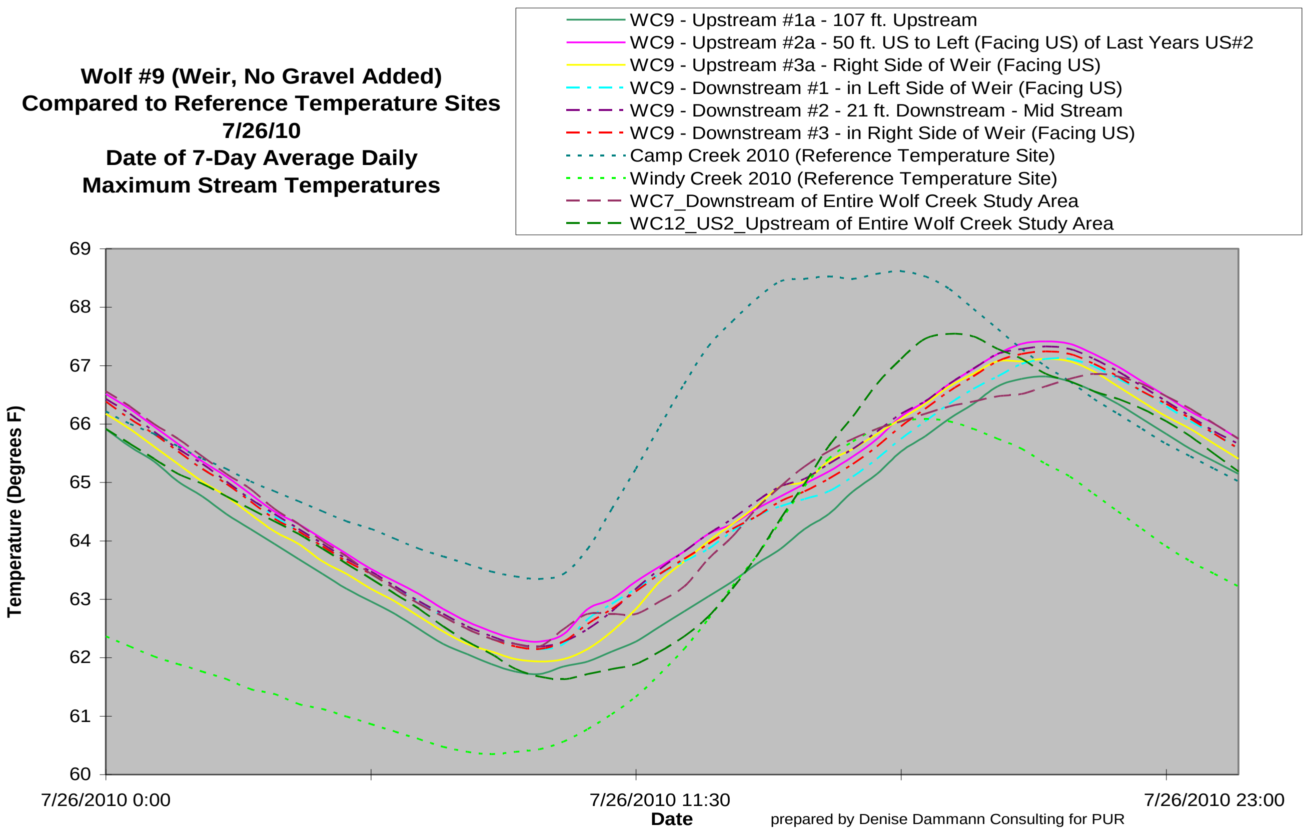


Figure 9. An example of using reference temperature data for comparing to other sites in the basin. 2010 Wolf Creek Restoration Sites #10 and #9 weir with gravel augmentation and weir without gravel augmentation compared with Reference Temperature Data (Dammann, 2010). The Wolf Creek drainage above this site is 17,180 acres, while Windy Creek is 15,260 and Camp Creek is 22,550 for comparison. Flow data used to determine low flow dates are from Oregon Water Resources Department (PUR, 2010). (Page 1 of 2)



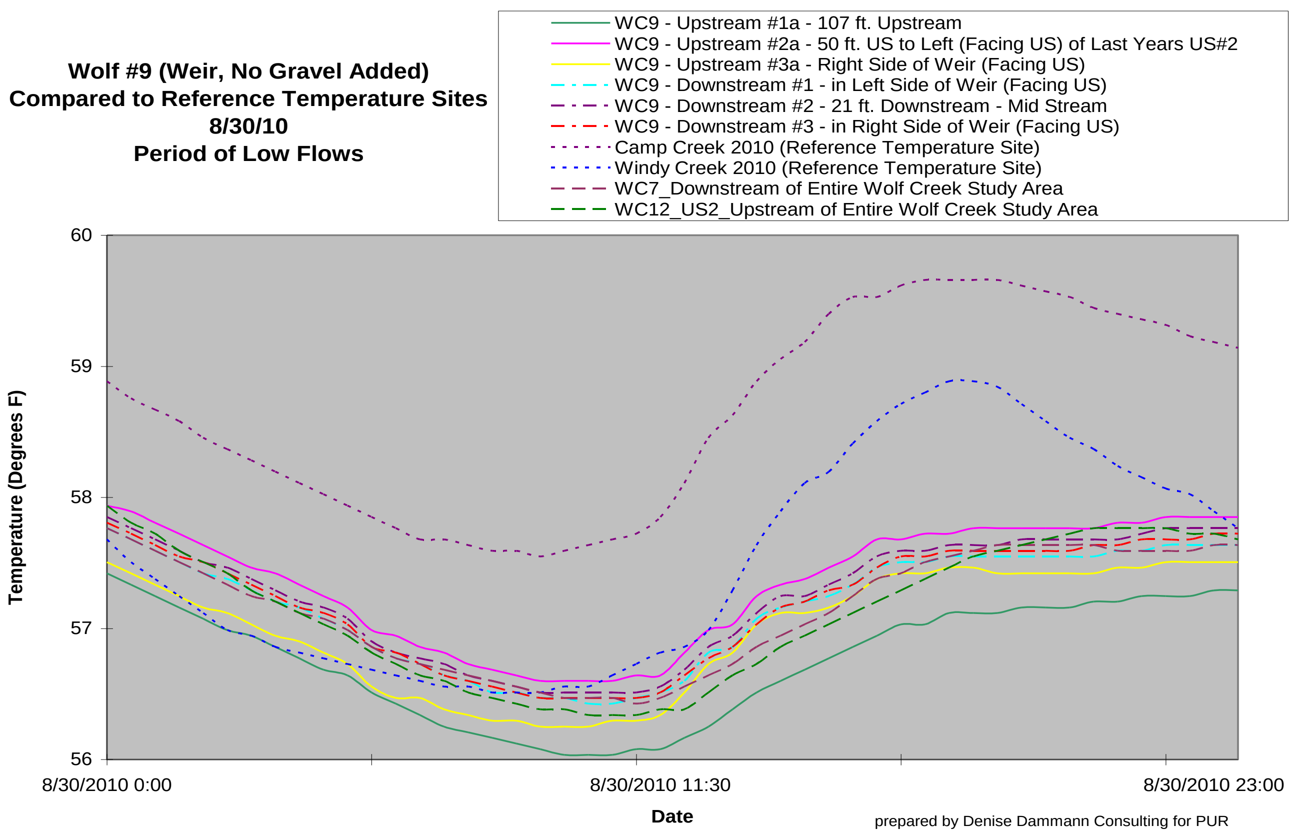


Figure 9. Continued. (Page 2 of 2)

References:

Arismendi, I., S. Mohammad, S.L Johnson, J.B. Dunham, R. Haggerty. 2013. Increasing synchrony of high temperature and low flow in western North American streams: double trouble for coldwater biota? Hydrobiologia 712(1): 61-70.

Beschta, R.L., R.E. Bilby, G.W. Brown, L.B. Holtby, and T.D. Hofstra. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. in: Salo, E.O. and T.W. Cundy (eds.). Streamside Management: Forestry and Fishery Interactions. College of Forest Resources, University of Washington, Seattle, Washington. Pages 191-232.

Brown, G.W. 1969. Predicting temperatures of small streams. Water Resources Research 5(1): 68-75.

Clews, E., I Durance, I.P. Vaughan, and S.J. Ormerod. 2010. Juvenile salmonid populations in a temperate river system track synoptic trends in climate Global Change Biology. 16(12): 3271-3283.

Dammann, D.M. 2007. Umpqua Basin Stream Temperature Characterization – Reference Site Update 2007. Partnership for the Umpqua Rivers (PUR), Roseburg, Oregon.

Dammann, D.M. 2008. Umpqua Basin Stream Temperature Characterization – Reference Site Update 2008. Partnership for the Umpqua Rivers (PUR), Roseburg, Oregon.

Dammann, D.M. 2009. Umpqua Basin Stream Temperature Characterization – Reference Site Update 2009. Partnership for the Umpqua Rivers (PUR), Roseburg, Oregon.

Dammann, D.M. 2010. Umpqua Basin Stream Temperature Characterization – Reference Site Update 2010. Partnership for the Umpqua Rivers (PUR), Roseburg, Oregon.

Dammann, D.M. 2011. Umpqua Basin Stream Temperature Characterization – Reference Site Update 2011. Partnership for the Umpqua Rivers (PUR), Roseburg, Oregon.

Dammann, D.M. 2012. Umpqua Basin Stream Temperature Characterization – Reference Site Update 2012. Partnership for the Umpqua Rivers (PUR), Roseburg, Oregon.

Dammann, D.M. 2013. Umpqua Basin Stream Temperature Characterization – Reference Site Update 2013. Partnership for the Umpqua Rivers (PUR), Roseburg, Oregon.

Dammann, D.M. 2014. Umpqua Basin Stream Temperature Characterization – Reference Site Update 2014. Partnership for the Umpqua Rivers (PUR), Roseburg, Oregon.

Dammann, D.M. 2015. Umpqua Basin Stream Temperature Characterization – Reference Site Update 2014. Partnership for the Umpqua Rivers (PUR), Roseburg, Oregon.

Dammann, D.M. and K. Smith. 2006. PUR Umpqua Basin Stream Temperature Characterization – Reference Site Update – 2006 Data. Partnership for the Umpqua Rivers, Roseburg, Oregon.

Iowa State University of Science and Technology. 2016. Iowa Environmental Mesonet. http://mesonet.agron.iastate.edu/wx/afos/.

Lyon, S., K. Smith and D.M. Dammann. 2012. Final Report OWEB Grant 209-2052 PUR Water Quality Monitoring / DEQ Grant 013-10 PUR Water Quality Monitoring & Thermal Refugia Investigation. PUR, Roseburg, OR.

Mail Tribune. September 1, 2015. Medford's summer is one for the record books – again. Medford, Oregon.

National Weather Service. December, 2016a. National Weather Service – Local Climate: NOWData, Medford, Oregon. http://w2.weather.gov/climate/xmacis.php?wfo=mfr.

National Weather Service. December, 2016b. National Weather Service – Local Climate: NOWData, Portland, Oregon. http://w2.weather.gov/climate/xmacis.php?wfo=pqr.

National Weather Service. November, 2015a. National Weather Service – Local Climate: NOWData, Medford, Oregon. http://nowdata.rcc-acis.org/mfr.

National Weather Service. November, 2015b. National Weather Service – Local Climate: NOWData, Portland, Oregon. http://nowdata.rcc-acis.org/pqr.

The News-Review. July 29, 2009. Record heat slaps Roseburg. Roseburg, Oregon.

The News-Review. July 30, 2009. Whew! Another heat record established. Roseburg, Oregon.

The News-Review. September 2, 2015. Was it hot enough for you?: Roseburg this summer was hottest on record. Roseburg, Oregon.

Oregon Department of Environmental Quality (ODEQ). 2003. Figure 320A: Fish Use Designations Umpqua Basin, Oregon. www.deq.state.or.us/wq/standards/FishUseMapsFinal/FFigure320A_Umpqua.pdf

ODEQ. 2006. Assessment Methodology for Oregon's 2004/2006 Integrated Report on Water Quality Status. www.deq.state.or.us/wq/303dlist/docs/intgrrptassessmentmethod0406.pdf

ODEQ. 2011. Methodology for Oregon's 2010 Water Quality Report and List of Water Quality Limited Waters. Portland: ODEQ.

The Oregonian. July 29, 2009. Health concerns heat up. Portland, Oregon.

The Oregonian. July 30, 2009. Not the record, but whew! Portland, Oregon.

Partnership for the Umpqua Rivers (PUR). 2014. Streamwalker – Summer 2014 Final Report. Roseburg, Oregon.

PUR. 2015. Streamwalker – Summer 2015 Final Report. Roseburg, Oregon.

PUR. 2016. Streamwalker – Summer 2016 Final Report. Roseburg, Oregon.

The Register-Guard. September 2, 2015. Eugene summer was hottest on record, National Weather Service says. Eugene, Oregon.

Smith, K. 2001a. Umpqua Basin Stream Temperature Reports: 1999-2001. Umpqua Basin Watershed Council, Roseburg, Oregon.

Smith, K. 2001b. Use of a Control Site to Reduce Inter-Year Variability in Stream Temperature Data in the Umpqua Basin. Umpqua Basin Watershed Council, Roseburg, Oregon.

Smith, K. 2003. Stream Temperature in the Umpqua Basin Characteristics and Management Implications. Umpqua Basin Watershed Council, Roseburg, OR.

Smith, K. 2004. Umpqua Basin Stream Temperature 2004 Update. Umpqua Basin Watershed Council, Roseburg, OR.

Smith, K. 2005. UBWC Stream Temperature Characterization Project Reference Site Update 2005 Data. Umpqua Basin Watershed Council, Roseburg, OR.

Smith, K. 2010. Use of Synoptic Temperature Data to Reduce Inter-year Stream Temperature Variability within the Umpqua Basin. Partnership for the Umpqua Rivers, Roseburg, OR.

Taylor, G.H. and C. Hale. July 24, 2006. July Heat Wave Temperatures / Records. Oregon Climate Service. Oregon State University, Corvallis, OR.

Umpqua Basin Watershed Council. 2004. Streamwalker – Summer 2004 Final Report. Roseburg, Oregon.

Umpqua Basin Watershed Council. 2005. Streamwalker – Summer 2005 Final Report. Roseburg, Oregon.

Umpqua Basin Watershed Council {PUR}. 2006. Streamwalker – Summer 2006 Final Report. Roseburg, Oregon.

Umpqua Basin Watershed Council {PUR}. 2007. Streamwalker – Summer 2007 Final Report. Roseburg, Oregon.

Umpqua Basin Watershed Council {PUR}. 2008. Streamwalker – Summer 2008 Final Report. Roseburg, Oregon.

Umpqua Basin Watershed Council {PUR}. 2009. Streamwalker – Summer 2009 Final Report. Roseburg, Oregon.

Umpqua Basin Watershed Council {PUR}. 2010. Streamwalker – Summer 2010 Final Report. Roseburg, Oregon.

Umpqua Basin Watershed Council {PUR}. 2011. Streamwalker – Summer 2011 Final Report. Roseburg, Oregon.

Umpqua Basin Watershed Council {PUR}. 2012. Streamwalker – Summer 2012 Final Report. Roseburg, Oregon.

Umpqua Basin Watershed Council {PUR}. 2013. Streamwalker – Summer 2013 Final Report. Roseburg, Oregon.

U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). 2016. Oregon Basin Outlook Report: May 1, 2016. Portland, Oregon.